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PRELIMINARY ESTIMATION OF COLOR INHOMOGENEITIES ON THE SURFACE OF VENUS ACCORDING TO THE TELEVISION IMAGES OBTAINED BY THE VENERA-13 AND VENERA-14 AUTOMATED SPACE PROBES

Yu. G. Shkuratov, M. A. Kreslavskiy and A. T. Bazilevskiy

Translation of "Predvaritel'nyye otsenki tsvetovykh neodnorodnostey na poverkhnosti venery po dannym televizionnoy s"emki ams Venera-13 i Venera-14," in Pis'ma v astronomicheskiy zhurnal, Vol. 12, No. 10, 1986, Akademiya nauk, SSSR, Moscow USSR, pp. 795-800.

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16. Abstract

Digital processing of images obtained by the Venera-13 and Venera-14 probes led to the discovery of faint ($\leq$ 10%) color differences of some areas of the observed surface. Maximum color differences were observed in the right part of 14-1 panorama. Color anomaly is associated with the bedrock outcrop having slightly higher albedo than the surrounding. Possible causes of the discovered color differences are discussed.

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PRELIMINARY ESTIMATION OF COLOR INHOMOGENEITIES ON THE SURFACE OF VENUS ACCORDING TO THE TELEVISION IMAGES OBTAINED BY THE VENERA-13 AND VENERA-14 AUTOMATED SPACE PROBES

Yu. G. Shkuratov, M. A. Kreslavskiy and A. T. Bazilevskiy

During an analysis of panoramas transmitted by the Venera-13 and Venera-14 automated space probes, digital processing led to the discovery of faint (no more than 10%) color differences on certain sections of the observed surface. Maximum color differences (0.63 μm/0.53μm) were observed in the right part of panorama 14-1. The color anomalies are associated with rock formations which have a light phototone. The possible causes of the weak shades of color detected are discussed.

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The first panoramas of the Venusian surface were obtained in March 1982 using television devices mounted on the landing modules of the Venera-13 and Venera-14 automated space probes using light filters (Selivanov et al., 1983; Florenskiy et al., 1982). This material made it possible to look at the Venusian rock in natural light (Bokshteyn et al., 1982) and also, according to Pieters report (1985) at the Soviet-American working meeting on problems of studying Venus, held in Moscow, to model the color of the surface in conditions of direct illumination by solar rays.

We have attempted to use the panoramas obtained for evaluating the color contrasts on the surface of Venus by a method of cluster analysis which we had used earlier for processing data of radar images of the Venusian surface obtained by the Pioneer-Venera-1 (Bazilevskiy et al., 1982). The results presented here are still preliminary.

The stages for processing televised panoramas in digital recording obtained at IPPI AN SSSR [Institute of Information

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Transmission Problems of the Academy of Sciences, USSR] were the following. First, according to recordings corresponding to filters 0.62 and 0.53 μm, color separation images were constructed (0.62/ /796 0.53 μm). These images appeared to be noticeably noisy and therefore for further processing only a fragment of panoramas 14-1 were selected where the level of noise was minimum (see Figure 1). Here, in the

Figure 1. Fragment of television panorama 14-1. On the right, a color test separates an area which has a color indicator (0.62/0.53 μm) approximately 7-10% higher than the surrounding area.

field of vision of the television camera, outcrops are found on the surface of horizontal-stratified consolidated rock not covered with a layer of loose soil. The thickness of individual layers making up this complex member and forming (during selective rupture on the surface) characteristic combinations of benches and leveled areas, varies from a few millimeters (limit of resolution capability) to 3 cm. The layers often show differences in brightness. The color differences of the layers have not been studied before. The finely horizontal-stratified character of the rock observed in

combination with their low strength (determined according to sibsidence) and typically basalt chemical composition indicate that these rocks, probably, were formed as the result of wind (wind-borne) precipitation accumulation of volcanic basalt ash or other products of surface breakdown of basalts (Bazilevskiy et al., 1985). For this fragment of the panorama, the light-separation and brightness images were filtered for separation of sections with the most level relief of the optical parameter. Filtration was done by analysis of the spread of brightness (color) in the environs of each element of the image according to 10 adjoining elements. On the fragment, only those areas (about 60-70% of the area of the frame) were selected which corresponded to the smallest root mean square deviation and only for these areas was a cluster analysis carried out. Figure 2 shows the diagram of brightness (0.62 μm) -- color (0.62/0.53 μm) of the fragment studied. The values of brightness and color are given in conventional units. The levels of encounterability of combinations of brightness-color, identified by different hatchings from the periphery to the center, relate as 1:4:16:32:64:128. On the brightness-color diagram, areas of the best combination of parameters are isolated, that is, clusters. Four clusters are reliably isolated which can be seen on the diagram shown in Figure 3. In the image this cluster corresponds to the area identified in Figure 3 by this same type of hatching. An analysis of the images in Figures 1 and 3 shows the following. The first cluster corresponds basically to the area of s h a d o w f r o m a large stone and the landing module. It is of no further interest. Two other clusters differ in brightness but hardly differ in color. The differences in brightness also, probably, are due to shadow

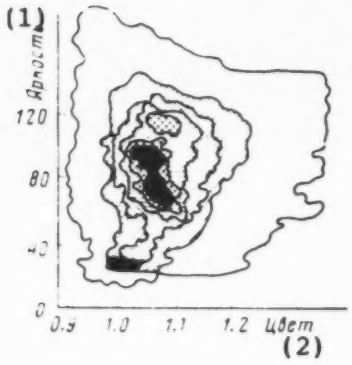

Figure 2. Diagram of brightness -- color of the surface, constructed on panorama 14-1 for the fragment in Figure 1.

Key: (1) brightness; (2) color.

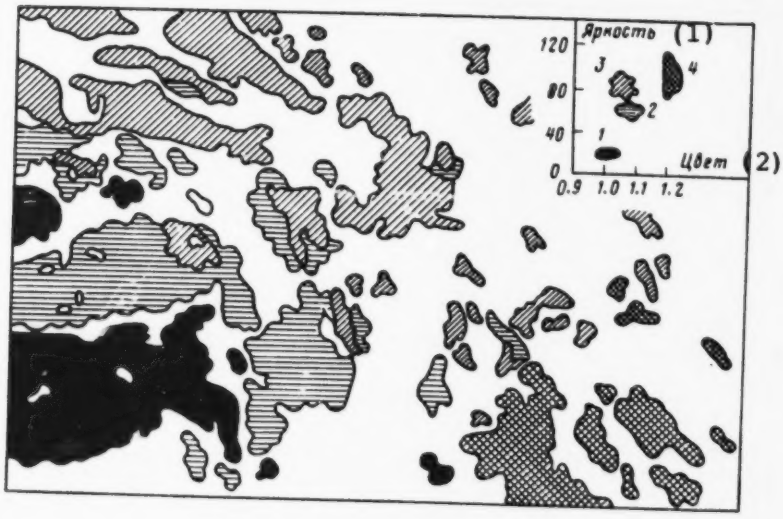

Figure 3. Diagram of optical types of rock for the fragment in Figure 1, compiled by a method of cluster analysis. In the right upper corner of the drawing is the diagram of brightness-color on which the clusters are isolated. The type of hatching of the areas on the insert corresponds to the hatching of clusters on the diagram.

Key: (1) brightness; (2) color.

caused by the landing module. It is visible from the position of the areas corresponding to clusters 2 and 3 on the image: these areas are shifted one relative to the other along the radius applied from the center of the landing ring of the vehicle. Finally, the fourth cluster, which is a continuation of the third (see Figure 2) is noticeably shifted along the axis of color by approxiamtely 7-10% and hardly differs in value of intensity. The areas corresponding to this cluster lie approximately on a single radius with the areas corresponding to the third cluster and therefore they can compare ith each other assuming uniformity of conditions of their illumination. On fragment of panorama 14-1 the areas of the fourth cluster located to the right of the colored test corresponds to outcrops on the surface of the rock, differing in no way from the adjoining in morphology, but occupying a higher gypsometric position than the

adjacent and therefore, probably, belonging to a different layer. Turn your attention to the central part of the rock outcrop circled in Figure 1. It shows several other brighter sections on the phototone. The color and brightness properties of this section we tend to ascribe to the formation itself, and not to a possible peculiarity of its lighting. In this way, probably, in this case, we are dealing with slight differences in the chemical-mineralogical composition and/or the special features of the structure of the scattered layer.

The basic chromophore in the basalt composition rock, as is well known, is iron. The slope of the curve of the spectral albedo of such rock in the visible region is controlled primarily by the relationship Fe^{3+}/Fe^{2+}, which, in turn significantly depends on the degree of oxygen in the basalt. The data presented in Figure 4 can be evidence of this. These data were obtained when photographing spectra of the diffuse albedo on the Khitachi EPS-3T spectrophotometer; then, all of the spectral curves were standardized at the wavelength 0.7 μm. It is apparent from Figure 4 that the slope of the curve depends on the degree of weathering of the basalts: the higher the content of oxygen the higher is the color index 0.62/0.53 μm. Here, appropriately, one notes considerable differences between the spectral course of the albedo of the samples of basalt and the measurements on the surface made using the spectrophotometer on the landing modules of the Venera-9 and Venera-10 automated space probes (Golovin et al., 1983). According to the laboratory experiments made by Pieters (1985), these differences can be explained by the high

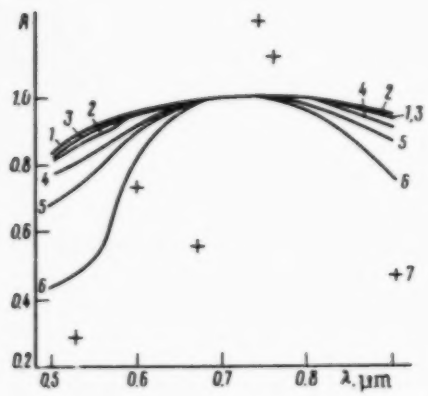

Figure 4. Spectral dependence of the albedo of the surface of Venus and samples of basalts with varying degree of oxidation: 1-3 fresh basalt; 4-6 weathered; 7 spectrophotometer data from the Venera-10 (Golovin et al., 1981).

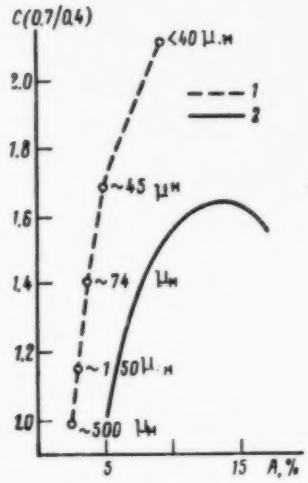

Figure 5. Diagram of the albedo -- color. 1 - Data of measurements of samples of basalts with varying particle size (from 40 to 500 μm) made by Adams and Filice (1967), 2 - calculated curve obtained according to the formula of the model of piles (Bondarenko et al., 1985) for the index of refraction n = 1.5, the index of absorption $\times = 5 \cdot 10^{-4}$ and the range of changes in dimensions of particles from 60 to 500 μm.

temperature on at which basalt is found on the surface of Venus. This result is in agreement with earlier results by Zang et al. (1977) who studied the effect of temperature on the parameters of the band of absorption of silicates.

Returning to the color differences detected on panorama 14-1 it was possible to propose that they are caused by different degrees of oxygen in the substances from different layers of the pile of rock or by some other reasons of a chemical-mineralological /799 nature. However, there can be other mechanisms leading to this same result. For example, variations of the average dimensions of the grains from which the rock is composed. According to the data of laboratory spectrophotometric measurements (Adams and Filice, 1967) and also the results of numerical modeling of the diagram of the albedo -- color, obtained in the work of Bondarenko et al. (1985), at low albedos (less than 10%) variation in dimensions of particles can have a noticeable effect on the value of the index of color and then hardly affect the albedo of the scattered layer. Figure 5 shows confirmation of these data. At the present time it is impossible to make a definite choice between different mechanisms capable of affecting the color of Venusian rock. New data are required obtained using descent space vehicles; these data must be combined with laboratory model optical experiments.

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